FINAL REPORT

CONTRACT #N00014-89-D-0255-0001, 0002

CONTRACT PERIOD 1 SEPTEMBER 1989 - 30 JUNE 1991

By

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August 31, 1994

CMD W.A. McIsaac
Office of Naval Research, Code 33B
800 N. Quincy Street
Arlington, VA 22217-5000

Dear CMD McIsaac:

Attached is the final report for contract #N00014-89-D-0255. The report covers efforts funded on delivery orders 001 and 002.

Sincerely,

Larry D. Flick
Center Administrator
Deep Submergence Laboratory

xc: Mr. Robert Tanner (copies - 1)
Director, Naval Research Laboratory (copies - 1)
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ABSTRACT

This final report deals with a portion of a long-term funding relationship between the Deep Submergence Laboratory at the Woods Hole Oceanographic Institution and the Deep Submergence Systems Division (OP-23), Office of the Chief of Naval Operations. That portion of time extends from 1 September 1989 to 30 June 1991, during which time two specific efforts were carried out. The first to be discussed is called BANGOPS II which dealt with a long-term survey of Hood Canal using the remotely operated vehicle *Jason* and a variety of side-scan sonar systems. The second major effort carried out in the fall of 1989 involved the combined use of the remotely operated vehicle *Jason*, the DSL-120 side-scan sonar, and the manned submersible DSV *Turtle*. This latter effort was carried out aboard the R/V *Laney Chouest* and involved a detailed survey of Forty Mile Bank off the southern coast of California. The multi-narrow-beam mapping system Sea Beam which is mounted on the *Laney Chouest* was also used as a part of this survey.

BANGOPS II

The 1989 program represented a significant advance over that of the previous year. The operation strategies were similar: a wide area towed sonar survey to identify terrain types and event locations followed by a detailed survey and event prosecution utilizing the ROV *Jason* . The navigation scheme was also similar. An integrated surface/subsea navigation system was used to fix the position of the *Jason* vehicle in world coordinates and in real time. The sensors, platforms, and data management techniques, however, were very different.

During BANGOPS I we utilized a conventional Klein 100 kHz side-looking sonar record in analog mode only. Event location was calculated manually, off-line, and with considerable error in slant-range and fish position. No swath-bathymetric data was available. During BANGOPS II we employed the DSL-120 swath-bathymetric sonar. This allowed us to localize and archive events in real time (point and click on screen) either in ship relative or real world coordinates. The DSL-120 also allows the collection of fine-scale swath-bathymetry (not yet processed in real time because of high data rates) that complements the side-looking imagery. The net result was a dramatic increase in the ability to locate and prosecute targets with the *Jason* system.

BANGOPS I was conducted onboard a contract ship (R/V *McGaw*) with representatives from the unmanned vehicle group offering some assistance. During BANGOPS II the operation was conducted aboard the DSVSS *Laney Chouest* with full cooperation and technical support of the Deep Submergence Unit and Unmanned Vehicle Group. The talent bases were complementary and the exchange of ideas benefitted both parties equally.

During BANGOPS I we surveyed a 10 kilometer by 1 kilometer area extending from just below the Delta Pier to just south of Squamish Harbor. BANGOPS II allowed us to resurvey the BANGOPS I area (for calibration and evaluation) and then extend the survey 18 kilometers to the north to a point just north of Foulweather Bluff (total distance covered in BANGOPS II was 28 kilometers). The area covered attests not only to the improved sensors, data handling, and talent bases of the operational team but to our familiarity with the environmental conditions in the area.

Typical maximum current velocities in the Hood Canal are in the 1 to 2 knot range and the current direction is variable in space and time. Visibility is very poor; usually in the 1 to 2 meter range. The *Jason* system is designed for deeper water use where currents are small (<.5 knots). Our experience in BANGOPS I, however, allowed us to develop an operational scheme of conducting station work during periods of low tidal activity and transect work during maximum flood and ebb tide. The current can be used to advantage if proper planning occurs. At times the *Jason* vehicle was able to make better than 2 knots over the seafloor. It is important to test the operational scheme under adverse conditions in order to define limits on effectiveness.

We achieved nearly 400% acoustic coverage for the area south of the bridge. Redundant coverage is important to our data processing and modelling schemes. Redundancy also allows for event verification and advanced analysis. All events were archived and entered into our GIS system for later retrieval. After prioritization, nearly 80% of the high-priority targets were prosecuted with the *Jason* vehicle. The subsea data set is classified at the secret level and will be presented elsewhere.

TACTICAL TERRAINS EXPERIMENT SOUTHERN CALIFORNIA REGION ("TACTEX '89 - SOCAL")

During November of 1989 the Deep Submergence Laboratory of the Woods Hole Oceanographic Institution, in collaboration with the Submarine Development Group One of the United States Navy, conducted a multiplatform field program along the trace of the San Clemente escarpment west of San Diego, California. The primary objectives of the operation were:

(1) to demonstrate new tools and techniques for application to naval operations in tactical underwater terrains;

(2) to conduct engineering field tests of new capabilities for multiscale, multisensor seafloor characterization; and

(3) to complete a limited scientific field program demonstrating the combined operational capabilities of the two organizations.

The intensive four-day exercise was designed to acquire and synthesize multisensor data starting at the coarsest scale (Sea Beam), progressing through medium resolutions (120 and 200 kHz swath-bathymetric sidescan sonars) to the finest level using man-in-the loop systems (optical imaging and seafloor sampling with DSV *Turtle* and the *Jason*-MEDEA system). Information acquired from the larger scales of survey data was applied successively to finer scales of operation to enhance on-site, tactical decision making. During unmanned-vehicle deployments, dynamic positioning and automated trackline-following techniques were employed to maximize operational efficiency.

The exercise was highly successful: all planned components were completed on schedule with no delays caused by equipment failure or inclement weather. Toward these ends, the multiscale approach was demonstrably invaluable in accomplishing all mission requirements within the tight scheduling window. Beyond meeting the immediate operational goals, a unique multisensor data set was acquired that will be applied to ongoing engineering research programs having tactical-terrain applications. These data will also enhance the results of the geological investigations undertaken as part of the exercise. The overall success of the program may be attributed in large measure to the cooperative efforts of DSL and SUBDEVGROUP 1 and the synergistic exchange of ideas and techniques between the two gorups.

The initial report of the TACTEX '89 - SOCAL program is attached.

Preliminary Cruise Report

TACTEX '89 - SOCAL

Tactical Terrains Experiment
Southern Californian Region

Dr. David Gallo, Dr. Kenneth Stewart, and Dr. Robert Ballard

Deep Submergence Laboratory
Woods Hole Oceanographic Institution

Executive Summary

During November of 1989, the Deep Submergence Laboratory of the Woods Hole Oceanographic Institution, in collaboration with the Submarine Development Group One of the United States Navy, conducted a multiplatform field program along the trace of the San Clemente escarpment west of San Diego, CA. The primary objectives of the operation were: (1) to demonstrate new tools and techniques for application to naval operations in tactical underwater terrains; (2) to conduct engineering field tests of new capabilities for the multiscale, multisensor seafloor characterization; and (3) to complete a limited scientific field program demonstrating the combined operational capabilities of the two organizations.

The intensive four-day exercise was designed to acquire and synthesize multisensor data starting at the coarsest scale (Sea Beam), progressing through medium resolutions (120-and 200-kHz swath-bathymetric sidescan sonars), to the finest level using man-in-the loop systems (optical imaging and seafloor sampling with DSV TURTLE and the JASON-MEDEA system.) Information acquired from the larger scales of survey data was applied successively to finer scales of operation to enhance on-site, tactical decision making. During unmanned-vehicle deployments, dynamic positioning and automated trackline-following techniques were employed to maximize operational efficiency.

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Background

During the past decade the emergence of a unique suite of marine imaging tools and data-processing techniques has revolutionized the manner in which the seafloor can be characterized. These tools operate over a spectrum of ranges and resolutions spanning large-scale, shallow-towed, or hull-mounted acoustic systems (e.g. GLORIA, SeaMARC II, Hydrosweep, Sea Beam); deep-deployed optical packages (e.g. ANGUS, ARGO, DEEP-TOW); and manned submersibles or remotely operated vehicles (e.g. DSV's ALVIN, SEACLIFF TURTLE; ARGO/JASON). Field operations can derive great benefit from large-scale (strategic) survey data that places the finer-scale (tactical) information in perspective.

Sea Beam, for example, offers a high-resolution (10 m contour interval) bathymetric description of sea floor topography at regional scales (10's to 1000's of km^2); however, the systems does not provide the finer-scale (i.e., 1-2 m contours over 0.1 to a few km^2) detail needed to support terrain-involved DSV or ROV operations. Experience shows also that the interpretation of seafloor imagery at all scales is also enhanced by reliable bathymetric data. In this respect, the integration of side-scan sonar imagery with complementary bathymetric data represents a powerful seafloor characterization technique.

Before now the sensors, platforms, and computational resources needed for the collection and interpretation of such tactical terrain information have been limited or unavailable. However, recent developments in these areas along with complementary advances in sensor processing, information management, and operational techniques offer new capabilities for assessment of underwater terrains. These include: the development of spatial database management systems; precision navigation and control; high-resolution, quantitative sensing; 3-D modeling and synthesis of multisensory information; integrated processing for tactical display; and creation and presentation of synthetic imagery.

TACTEX '89 Objectives

Ongoing development programs at the Deep Submergence Laboratory in such multisensor, multiscale techniques are now moving from the research phase toward practical field sea-going systems. The joint assets of Woods Hole Oceanographic Institution and Submarine Development Group One afford a strong operational testbed to demonstrate the new capabilities. Toward these ends, the primary objectives of the TACTEX '89 operation were: (1) to demonstrate new tools and techniques for application to naval operations in tactical underwater terrains; (2) to conduct engineering field tests of new capabilities for multiscale, multisensor seafloor characterization; and (3) to complete a limited scientific field program demonstrating the combined operational capabilities of the two organizations.

The intensive four-day exercise was designed to acquire and synthesize multisensor data starting at the coarsest scale (Sea Beam), progressing through medium resolutions (120-and 200 kHz swath-bathymetric sidescan sonars), to the finest level using man-in-the loop systems (optical imaging and seafloor sampling with DSV TURTLE and the JASON-MEDEA system). Information acquired from the larger scales of survey data would be applied successively to finer scales of operation to enhance on-site, tactical decision making. During unmanned-vehicle deployments, dynamic positioning and automated trackline-following techniques would be employed to maximize operational efficiency. Specific tasks to be accomplished included:

1. Large-scale acoustic mapping (sea Beam and 120-kHz swath bathymetric sonar).
2. Medium-scale acoustic mapping (200-kHz swath bathymetric sonar).
3. Fine-scale optical survey (TURTLE/JASON-MEDEA color and b/w imagery).
4. Geological reconnaissance (TURTLE and JASON).
5. Optical ground truthing and target verification (TURTLE and JASON).
6. Sample recovery (TURTLE and JASON).
7. Dynamic positioning tests using long-baseline acoustic positioning (ship only).
8. Dynamic positioning tests of ship/cable/vehicle system.
9. Demonstration of repeatable tracklines under dynamic positioning.
10. 200-kHz swath bathymetric sonar experiments.
11. Simulated side-/forward-scan sonar integration experiment.
12. Optical (black-and-white SIT Cam) mosaic of 50^2 meters.
13. Optical (CCD color video) mosaic of 10^2 meters.

Summary of Results

The pre-cruise operations plan specified deployment of a long-baseline acoustic net followed by a Sea Beam and DSL-120 SLS survey and then DSV TURTLE operations. However the GPS window beginning approximately 0000 on 28 Nov. precluded accurate nav-net deployment or SLS survey. Accordingly, a decision was made to deploy TURTLE first since the DSV goals were least effected by navigation, and the DSV was deployed to investigate a region beginning at the western flank of Forty Mile Bank, and continuing upslope into the primary operational area.

Following the TURTLE dive, a widely-spaced Seabeam bathymetric survey was conducted over a 4-nm^2 area to compile an accurate bathymetric framework within which to conduct subsequent operations. Based on Sea Beam charts prepared in real time, a 1-nm^2 region was selected as the focus of interest. Acoustic transponder locations were selected based on the Sea Beam survey, and the net was deployed and surveyed. Within this selected area, a 120-kHz swath bathymetric sonar survey was conducted to refine tactical information about the area, and to select sites for the fine-scale surveys.

Using wide-area information gathered during the Sea Beam and DSL-120 surveys, a survey strategy was prepared and DSV TURTLE deployed to continue geological reconnaissance upslope. The high resolution Sea Beam chart was distributed to the DSV pilots and NTCC personnel for assistance in tracking and maneuvering the submersible. Based on all available information obtained through this period, a site was selected for JASON deployment and fine-scale survey. The ship was maneuvered to the site and dynamic-positioning test commenced.

After a short period of tuning the long-baseline navigation and the ship's dynamic positioning system, 10-m watch-circle performance was achieved and JASON-MEDEA operations commenced. The vehicles were deployed to the bottom and additional dynamic-positioning tests of the ship/cable/vehicle system were conducted. After gaining operational experience over a t-hour period, a period of geological reconnaissance was undertaken to locate a west-facing fault scarp detected during the Sea Beam survey. The scarp was located and a 200-kHz sonar survey was conducted using a DSL DP-controller to run repeatable tracklines. Performance varied according to the direction of tracklines with respect to bottom currents, but repeatability was within a few meters on the most favorable orientation.

On completion of the DP/trackline tests, JASON was recovered to change camera orientation and to add a bottom-sampling tool. During the change-out interval, additional Sea Beam tracklines were surveyed for the purposes of refining coverage in key areas and to extend the survey area up to the maximum allowed by the schedule.

On completion of the Sea Beam survey, the JASON-MEDEA system was deployed for a second lowering at the original fine-scale survey site. Positioning was excellent and the scarp was reacquired visually as the vehicles approached bottom. Two photomosaic runs were conducted over the scarp for use in a mosaicking development program underway at DSL. A sample of rock fragments was taken with a JASON-mounted device. JASON-MEDEA operations concluded and the system was recovered.

A final TURTLE dive was undertaken to continue ground-truth observation for the acoustic survey, and was intended to make transects across the detailed survey area. The DSV was recovered early because of vehicle problems and transponder recovery commenced. A single transponder failed to respond to its release signal, and TURTLE's OIC made the decision to undertake a fourth dive to recover the transponder. After an unsuccessful search, DSV operations concluded.

Tools

Sea Beam

Sea Beam is a hull-mounted multi-narrow beam sonar system designed to allow accurate bathymetric mapping of seafloor terrains at ship speeds up to 15 kts. The system frequency is 12 kHz and each of 16 electronically formed beams is on the order of 2/3° representing a total beam width of about 42°. Bathymetric swaths produced by the Sea Beam system are therefore on the order of 2/3 the water depth and usable contour intervals are traditionally taken to be in the 10 meter range. Historically the Sea Beam system has revolutionized the manner in which the sea floor could be studied since it was the first mapping tool to allow "3-D" visualization of the sea floor topographic grain.

During the TACTEX '89 ops, more than 75 nm of Seam Beam tracklines were surveyed at a nominal track spacing of 200 meters. The survey was conducted in three phases and comprises: (1) wide-area coverage of a 4X3 nm operating area; (2) a strategic survey of a 2X2 nm area; and (3) more intensive coverage of the 1X1 nm intensive survey area.

DSL Split-Beam Sonars

The Deep Submergence Laboratory now operates 120-kHz and 200-kHz split-beam sonar systems designed for seafloor imaging and swath-bathymetric mapping. The sonars were developed by DSL in conjunction with the Applied Physics of the University of Washington and Acoustic Marine Systems of Redmond, Washington. The systems are fully calibrated so that accurate backscatter measurements can be made, and the dual-receiver design provides phase information that can be used to generate high-resolution swath bathymetry. Sophisticated surface processing is based on complex-domain cross-correlation techniques. A parallel signal processor comprising multiple computational notes provides real-time display of acoustic data at the surface. The fully configured system, still under development, will generate gray-scale imagery, color bathymetry, and sub-bottom profiles for real-time CRT and hardcopy presentation. All raw sonar data, along with navigation and attitude, are recorded in digital form for additional post processing.

During the TACTEX '89 ops complete 120-kHz coverage of the 1X1 nm intensive survey was obtained. These data were used to complement Sea Beam coverage and to assist in the selection of the fine-scale site. 200-kHz sonar data were obtained at this site over a 200X200 meter region.

Medea-Jason ROV

Platforms: The Medea-Jason system provides high-resolution real-time optical and sonar imagery. The system is two-bodied and unmanned. The Medea vehicle is a simple towed-camera sled and provides high altitude (10-20 meter) imagery. The Jason platform on the other hand is a remotely operated vehicle capable of conducting a wide variety of detailed survey and sampling tasks. The Medea and Jason vehicles are joined to each other by a fiber-optic tether, and both are controlled from a command center located aboard the surface vessel.

Sensors: The Medea system configured for the SOCAL ops consisted of a single down-looking color video camera. The Jason system was configured with two color video cameras (one down-looking, one forward pan-and-tilt) and two black and white video cameras (one down-looking silicon intensified target (SIT) video, one rear-looking). Optical imagery from the Medea and Jason system was provided and displayed simultaneously within the surface control van in order to provide a range of perspectives, ranges, and resolutions. In addition to optical imagery, the Jason system is equipped with 200 kHz split beam side-looking sonar capable of producing simultaneous swaths of bathymetry and acoustic imagery.

DSV TURTLE

DSV TURTLE, a unit of the Submarine Development Group One of the United States Navy, is a manned-submersible capable of carrying three passengers to an operating water depth of approximately 3200 meters. The TURTLE submersible is equipped with an optical suite including low light color video and a 35 mm color still camera. A sonar suite is designed specifically for search and obstacle avoidance. Two electro-hydraulic manipulators can be fitted with a variety of tools in order to meet sampling needs. DSV TURTLE is prepared for launch and recovery throughout a 24 day with practical operating speeds on the order of 1.5 kts and typical dive length for scientific missions of approximately 8 hours.

Three TURTLE dives were conducted within the SOCAL operations area. These dives were designed to provide optical ground-truthing to assist in characterizing the terrain types within the broader-scale acoustic imagery data and to provide a direct observation of geological features. Summaries of these dives are listed below:

Dive: 568-31 **Date:** 28 Nov 89
Pilot: LT James Hannan **Co-Pilot:** EMCS (SS) Kent Weekly
Observer: Dr. Mark Legg
Task: Reconnaissance of Western flank of Forty Mile Bank.
Summary: The western flank of Forty Mile Bank is characterized by a relatively steep western facing slope with regional gradients on the order of 10° - 20° punctuated by near vertical scarps. Scarp relief may be on the order of <1 to >10 meters. Scarp trends are generally east-west (parallel with the topographic grain observed in the sea beam maps). Several rock samples and sediment cores were recovered. This dive experienced fairly strong southerly currents (.5 kts).

Dive: 569-32 **Date:** 29 Nov 89
Pilot: LT Wade Allen **Co-Pilot:** MMC(SS) Peter Juhos
Observer: ENS Lynn Oschmann
Task: Reconnaissance of upper western flank and crest of Forty Mile Bank.
Summary: The uppermost portion of the bank is similar to the lower portion. Evidence of a tectonic boundary (fault) was documented by observation of distinctive changes in rock type. Several samples and sediment cores were recovered including a very large (30 lbs) fragment of deformed sedimentary rock that likely represents a fragment of the San Clemente fault system. The crest of Forty Mile Bank is blanketed by a uniform layer of cobble-sized rock fragments. Very little sediment cover was observed. This dive experienced moderately strong currents (.5 - .75 kts), particularly near the crest.

Dive: 570-33 **Date:** 1 Dec 89
Pilot: LDCR George Billy **Co-Pilot:** EMCS (SS) Kent Weekly
Observer: ET2 (SS/DV) William Carpenter
Task: Reconnaissance and geologic ground truthing of northern portion of Forty Mile Bank.
Summary: The northern flank of Forty Mile Bank is primarily a sedimented environment characterized mostly by sands. The sands are relatively homogeneous in character but the generally gently sloping seafloor is modified by current induced ripples. No hard rock outcrops or rock fragments were observed. This dive was curtailed by electrical failure.

Dive: 571-34 **Date:** 1 Dec 89
Pilot: LT James Hannan **Co-Pilot:** MMC (SS) Peter Juhos
Observer: MM1 (SS) Randy Comer
Task: Recover delinquent transponder.
Summary: Transponder # 3 failed to respond to multiple surface requests. An attempt was made to locate the transponder. The transponder was not located.

TACTEX '89 - SOCAL
Operations Summary

Monday
27 Nov 89

1846Z	Underway SOCAL OPS area. Transit to Forty Mile Bank.
2338Z	Arrive Dive Site 1. DSV TURTLE Dive 568-31. Goal of dive: Ascend southwestern flank of Forty Mile Bank, document terrain types and characteristics. Biological and geological sampling. Note: Proposed operations plan suggested long-baseline nav-net deployment followed by DSL-120 SLS survey and then DSV TURTLE operations. However GPS window beginning approximately 0000 hours on 28 Nov. precluded accurate nav-net deployment or SLS survey. Decision was made to deploy TURTLE first since the DSV goals were least effected by navigation. A Seabeam bathymetric survey was conducted after the DSV TURTLE OPS in order to compile an accurate bathymetric framework within which to conduct subsequent operations.
2340Z	Pre-dive meeting conducted by LCDR George Billy.
2348Z	End pre-dive meeting, positioning for Dive 568-31.

Tuesday
28 Nov 89

0022Z	DSV TURTLE in water.
0044Z	DSV TURTLE submerged.
0154Z	On bottom. Depth: 854 m.
0703Z	Off bottom. Depth: 335 m. DSV TURTLE on deck and secured. Begin Seabeam survey/start GPS window. N-S lines centered about general survey area. End Seabeam survey/end GPS window.
1244Z	Begin nav-net deployment. 5 transponders.
1754Z	End nav-net deployment.
1800Z	Begin Seabeam survey (N-S lines cont.)/GPS window.
1930Z	End Seabeam survey/end GPS window.
1945Z	Refine nav-net calibration.
2110Z	Begin Seabeam survey/start GPS window. E-W lines.
2311Z	End Seabeam survey.
2321Z	Prepare for DSL-120 launch.
2332Z	DSL-120 in water.

Wednesday
29 Nov 89

0000Z	DSL-120 out of water/Having trouble with launch over side A-Frame (FADOS).
0036Z	DSL-120 over side. Using small boat to pull fish away from Chouest.
0100Z	Start DSL-120 survey. Very good imagery.
0200Z	DSL-120 "dead". Recovering fish.
0245Z	DSL-120 on deck.
0353Z	DSL-120 repaired (Fiber replaced).
0408Z	Ready for DSL-120 launch. Maneuver to position.
0448Z	DSL-120 in water.
0458Z	DSL-120 survey resumes (running E-W lines).
2203Z	End DSL-120 survey. Start recovery.
2245Z	DSL-120 on deck and Secured.
2250Z.	Maneuver for DSV TURTLE Dive 569-32.
2340Z	DSV TURTLE in water.

Thursday
30 Nov 89

0105Z	DSV TURTLE on bottom. Depth: 2417 ft.
0645Z	DSV TURTLE off bottom. Depth: 717 ft.
	Prepare to launch Transponder #6
	Transponder #1 inadvertantly released.
	Reconstruct net. Calibrate.
	DP Test (Ship only).
	Maneuver for JASON OPS.
1439Z	Begin JASON OPS.

Friday
1 December 89

	JASON off bottom.
0720Z	JASON recovered/on deck/secured.
0725Z	Begin Sea Beam OPS
1215Z	End Sea Beam OPS/Maneuver for JASON OPS.
1340Z	Begin JASON OPS.
1516Z	JASON off bottom.
1535Z	JASON on deck/prepare for TURTLE OPS.
	Maneuver for DSV TURTLE Dive 570-33
1635Z	DSV TURTLE in water.
	DSV TURTLE on bottom.
	DSV TURTLE off bottom.
1800Z	DSV TURTLE on deck and secured.
	Maneuver for transponder recovery.

2347Z DSV TURTLE OPS to locate missing transponder.

Saturday
2 December 89

0419Z DSV TURTLE on deck and secured.
Transit to San Diego.

0900Z Arrive dockside North Island NAS

Participants

Woods Hole Oceanographic Institution
Dr. David Gallo
Dr. Kenneth Stewart
Dr. Dana Yoerger
Mr. Will Sellers
Mr. Martin Bowen
Mr. David Mindell
Mr. Robert Weiman
Mr. Robert Elder
Mr. William Hersey
Mr. Andrew Bowen
Ms. Lynn Oschman
Mr. John Kemp

United States Navy
LCDR Curtis Murphy

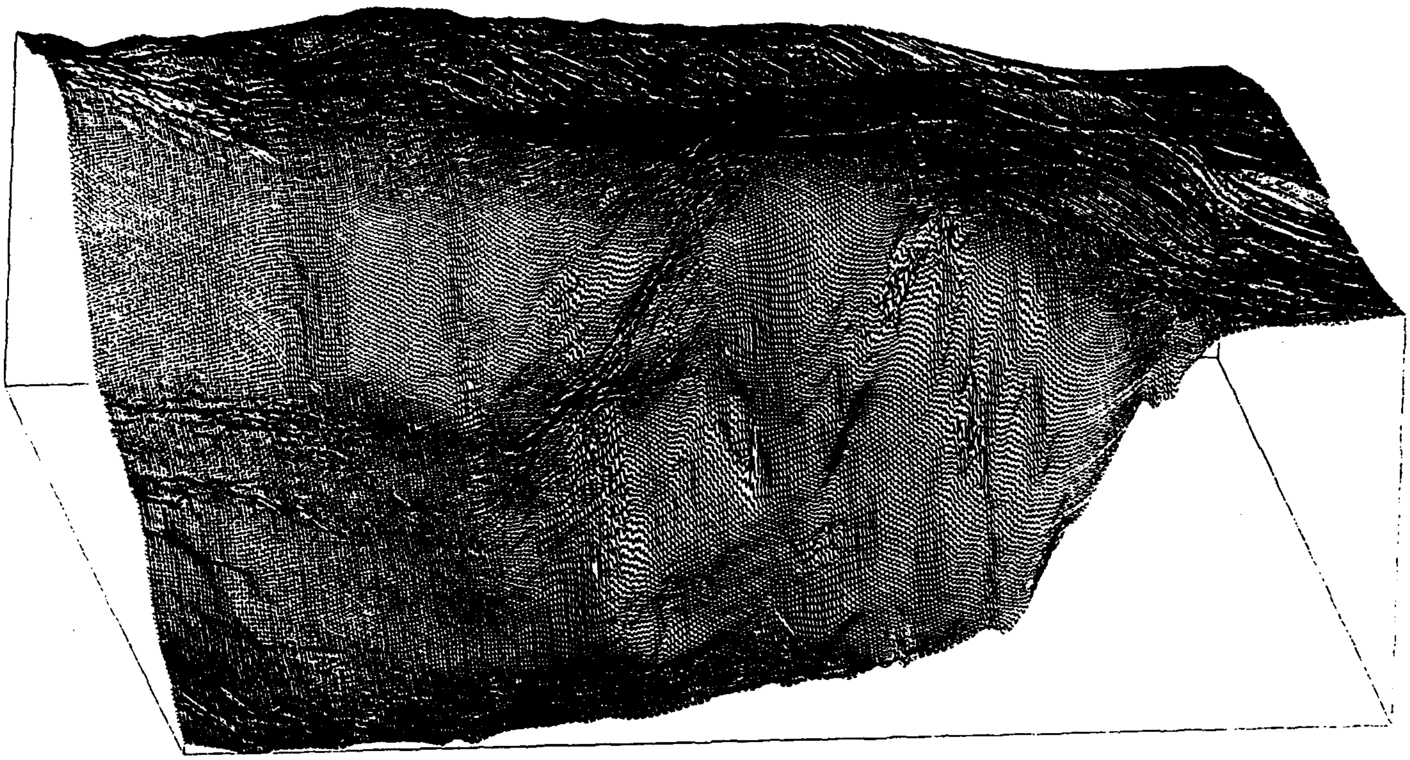
Naval Research Laboratory
Dr. Michael Czarnecki
Mr. Daniel Chayes

ACTA Inc.
Dr. Mark Legg

Acoustic Marine Systems
Mr. Irv Bjorkheim

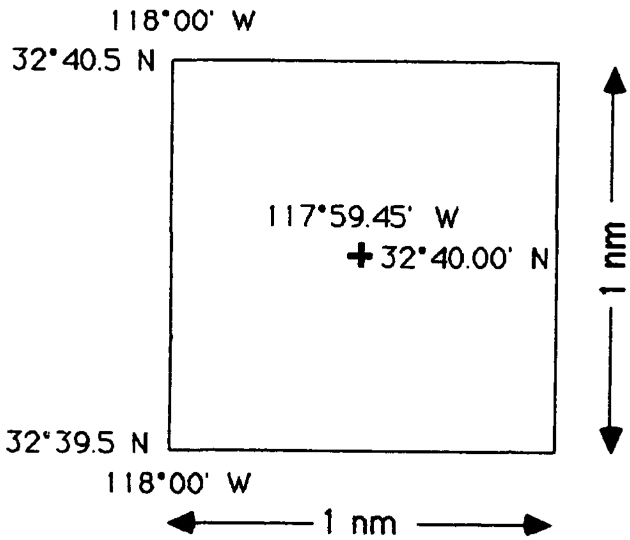
Pelagos Inc.
Mr. Stewart Canon

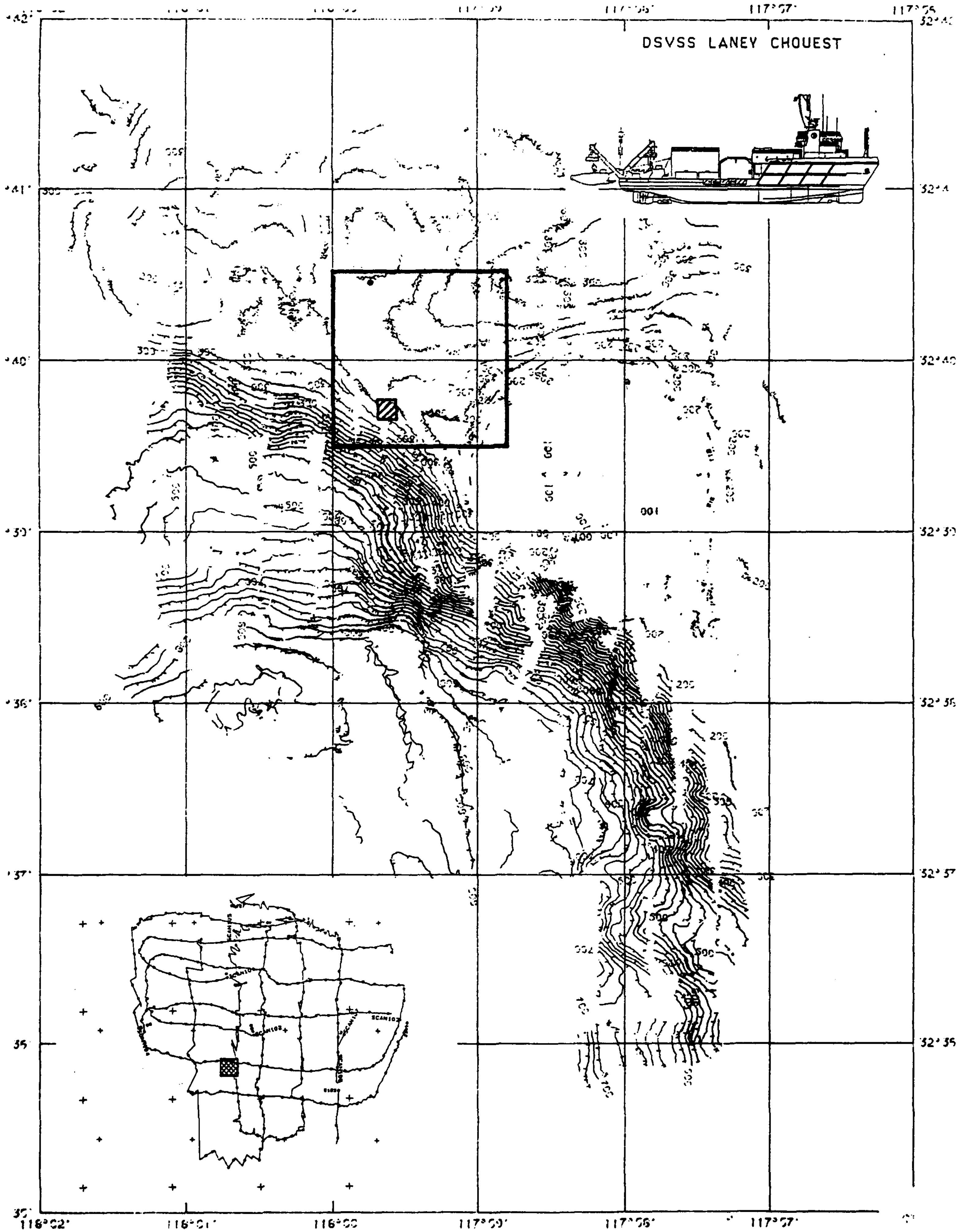
Submarine Development Group One
Unmanned Vehicles Detachment
STS2 Daniel Lord
ICC Randal Fricken
IC1 Daniel Harrington
ET1 Mark Cain
ET1 Mark Kiefer
STS1 John Holt
IC1 Sean Murphy



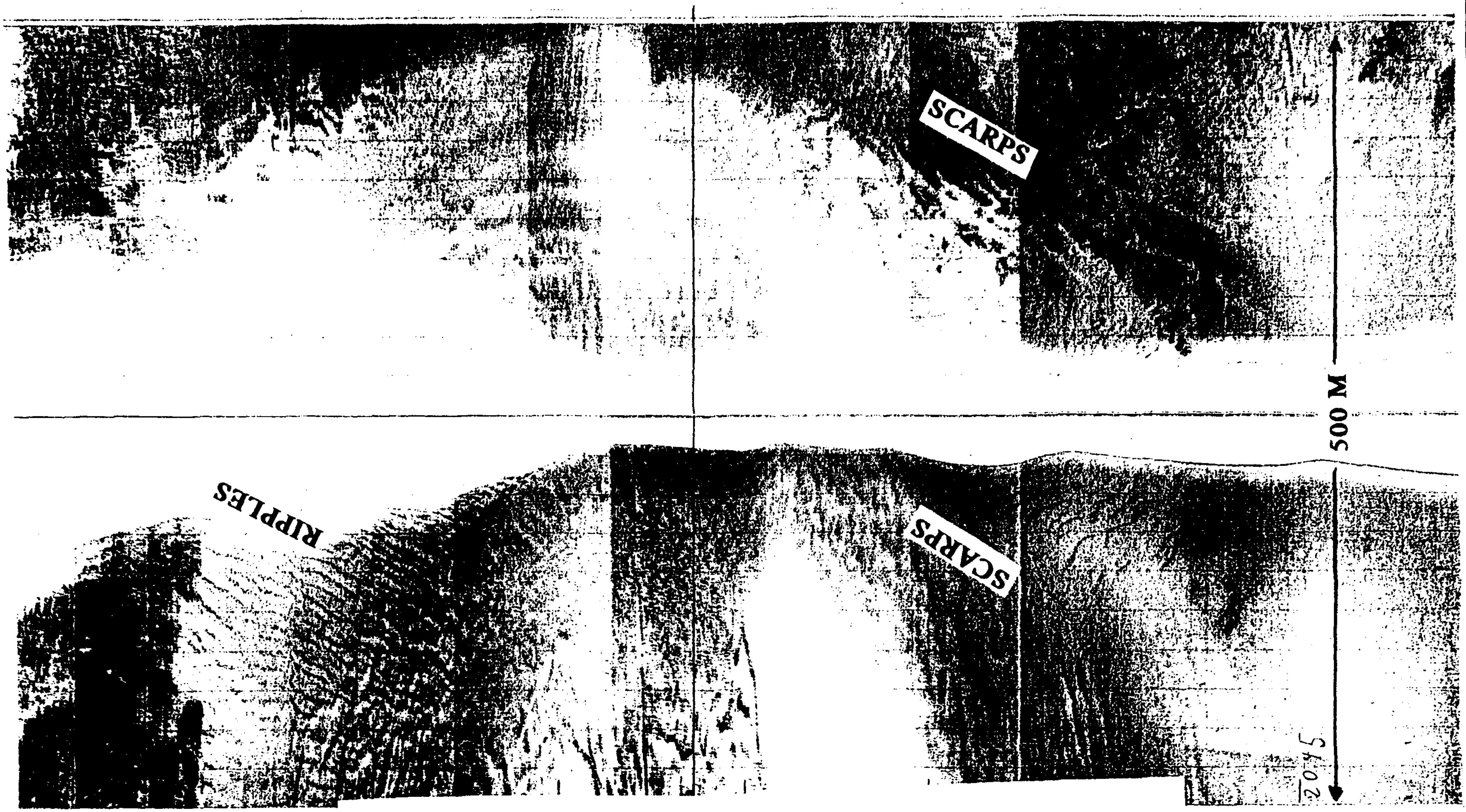
FORTYMILE BANK (PERSPECTIVE VIEW FROM THE SOUTH)
INPUT CHART SCALE = 0.00 IN/DEG, X-SPACING =0.029 IN.
ELEV = 20. DEG, AZIM = 10. DEG., Y-SPACING =0.029 IN
VERTICAL SCALE = .20E+03 METERS/INCH
LINEAR SCALE PLOTTED AT 1:0.03

TACTEX/SOCAL
Detailed Survey Area



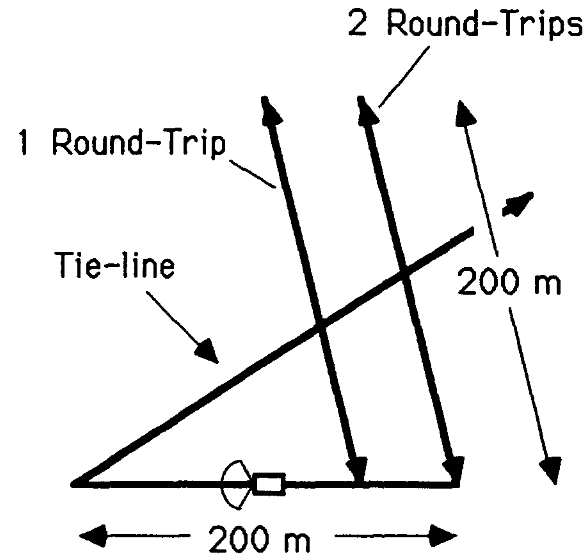


FORTYMILE BANK SEABEAM SURVEY

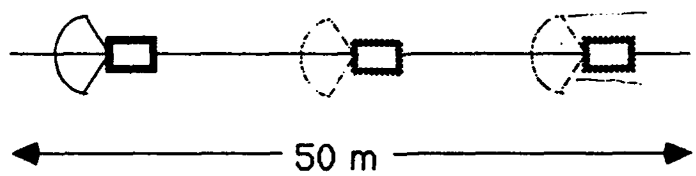


Example (unprocessed) of DSL-120 imagery. Swath width is 500 m. Complementary data (not shown) was collected simultaneously.

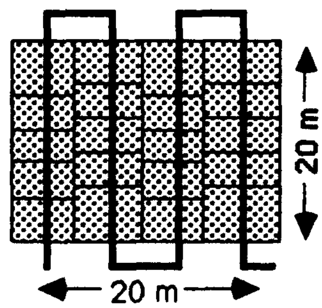
Medium-Scale Sonar Survey



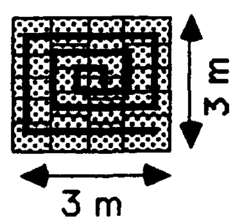
Integrated Side/Fwd Scan Experiment

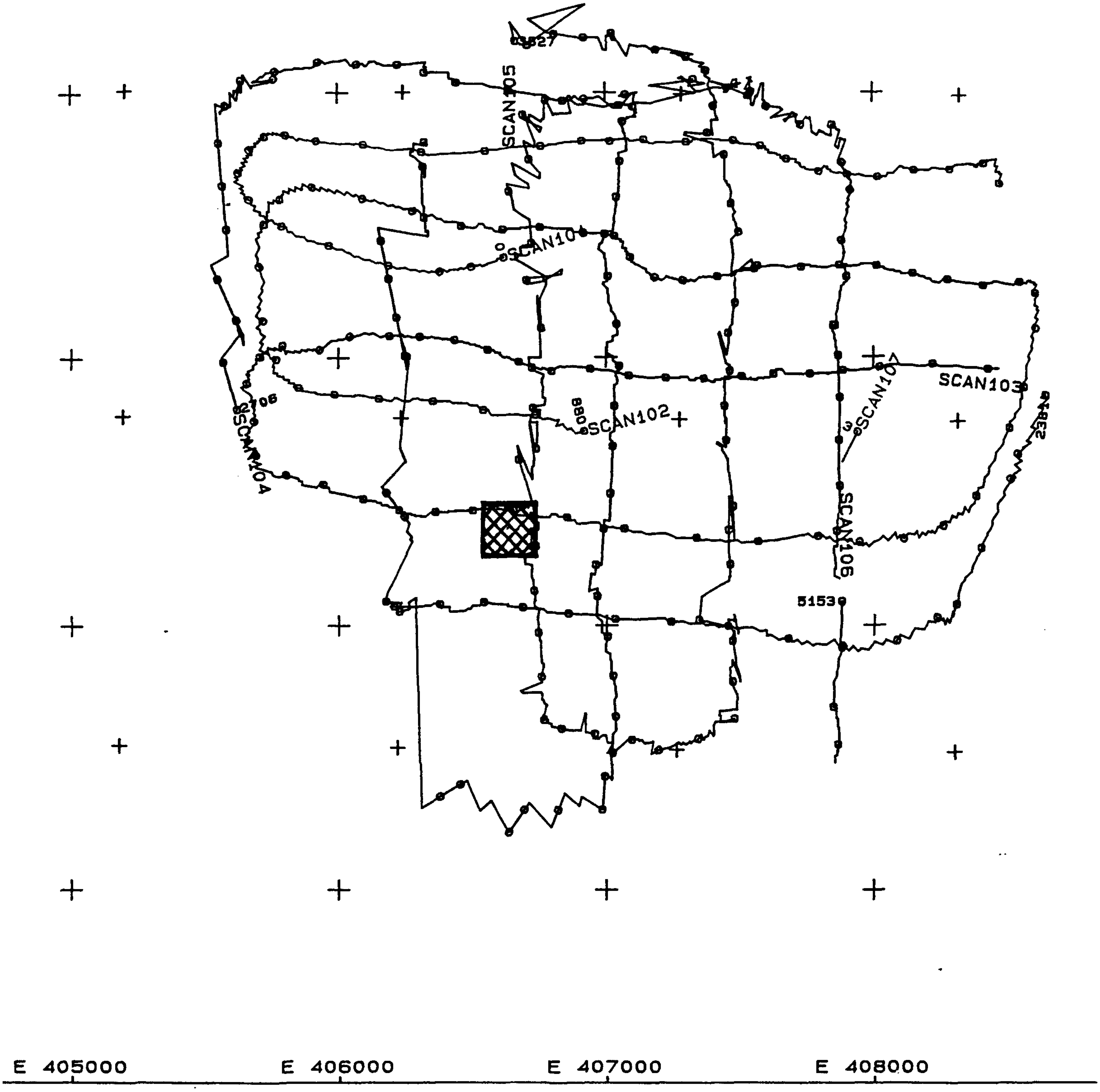


Fine-Scale Optical Mosaic



Micro-Scale Optical Mosaic





SCAN105
SCAN10
SCAN103
SCAN102
SCAN10A
SCAN106
51530
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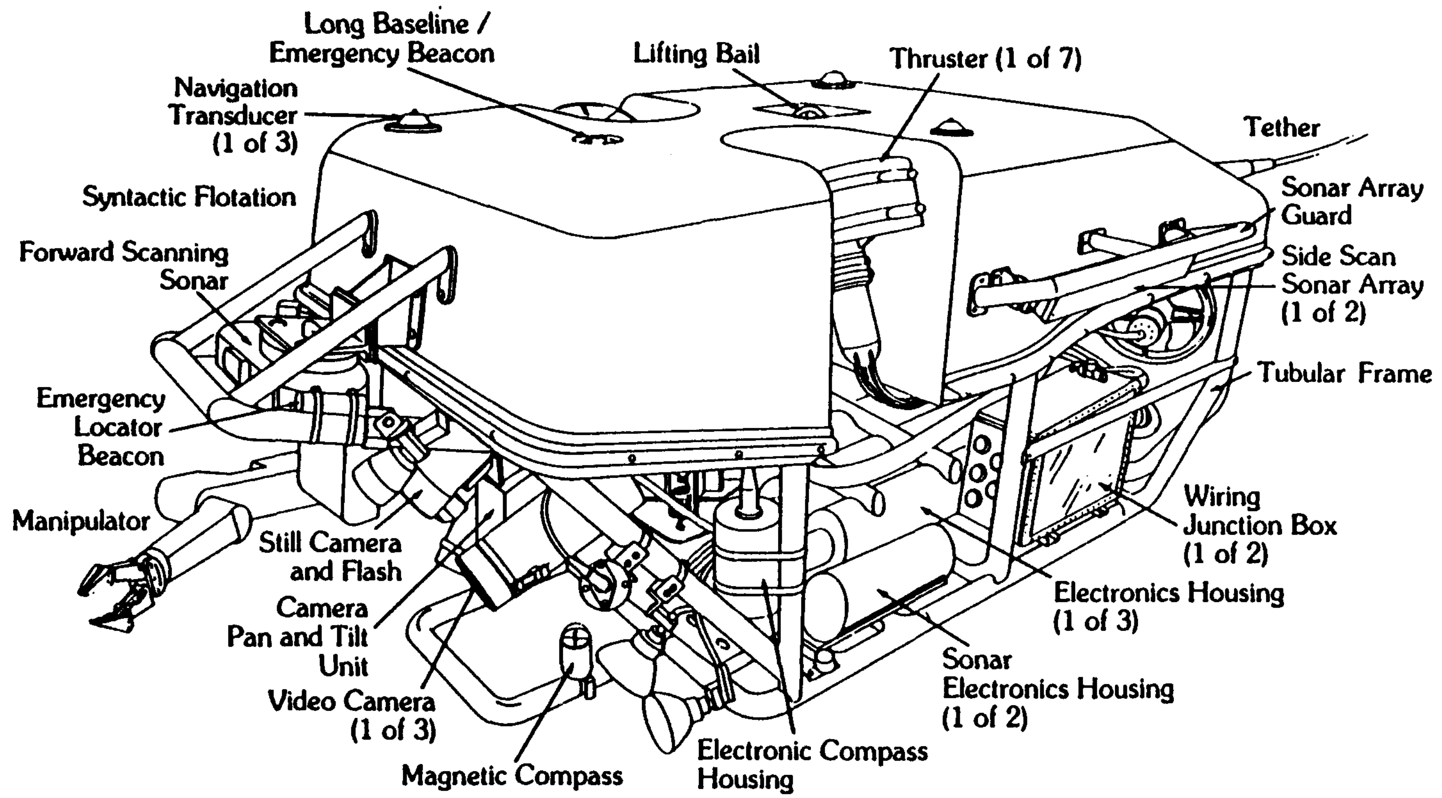
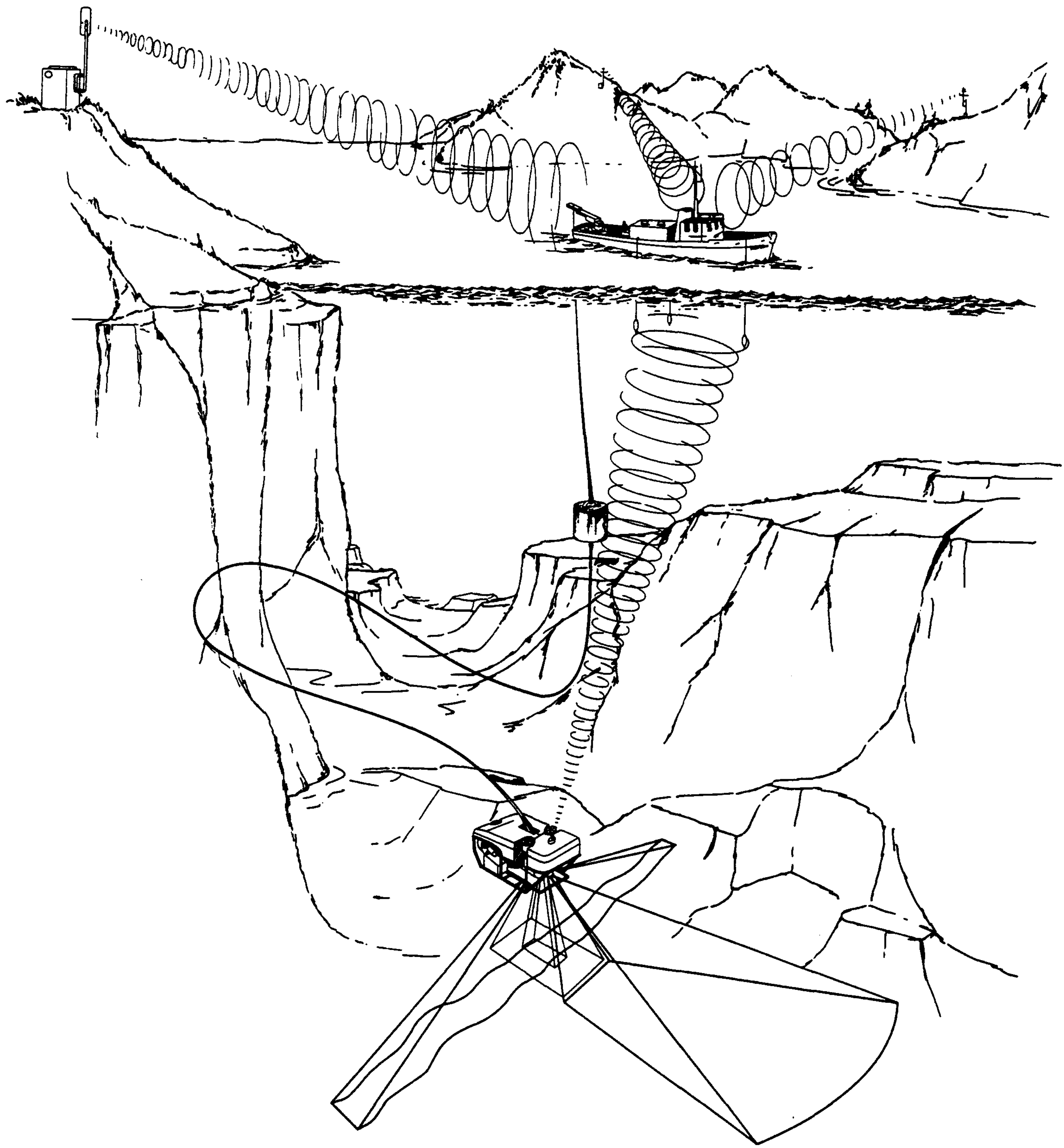


Figure A5: Schematic diagram showing JASON with propulsion, camera systems, and manipulator arms.



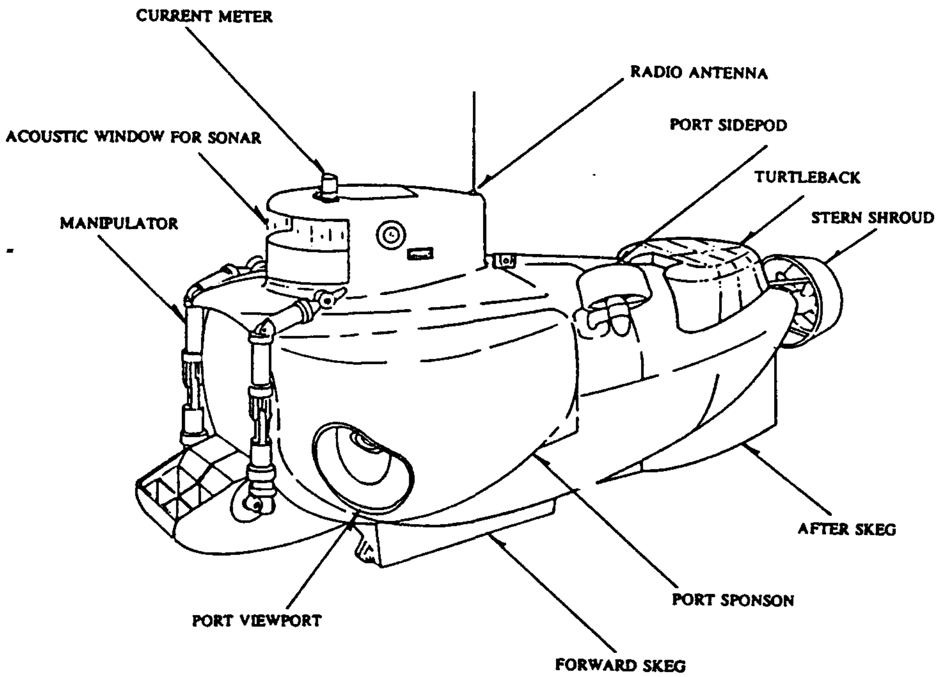
FORTYMILE BANK TURTLE DIVES

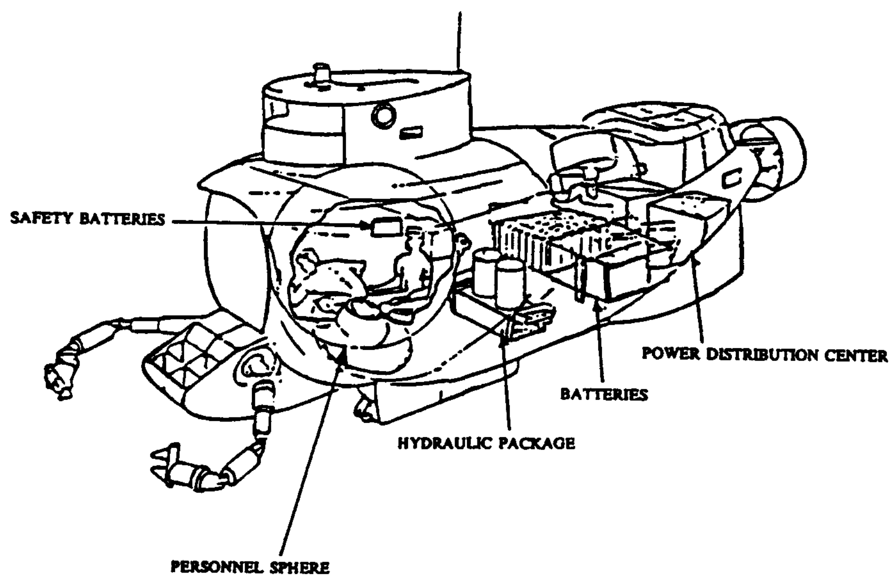
27 Nov - 1 Dec 1989

Mark R. Legg, & Lynn Oschmann

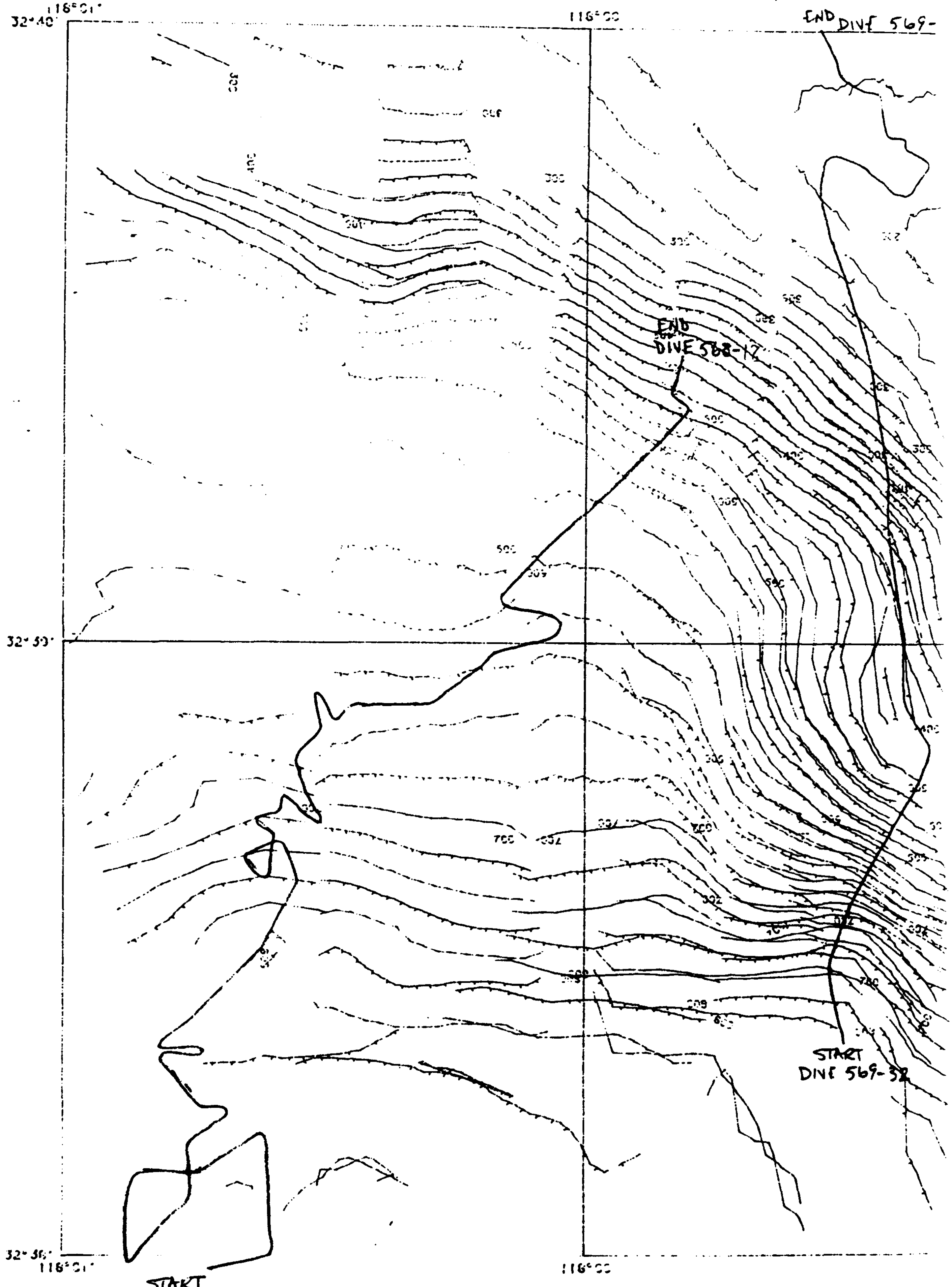
Fortymile Bank is a tectonically complicated part of the California Continental Borderland. It lies along the active San Clemente fault zone and numerous earthquake epicenters have been mapped nearby. Sea Beam and other remote sensing imagery have been successfully used to map the active submarine tectonic features, such as fault traces, in the area; yet, without actually bottom observations and sampling, we are uncertain of the true nature of the features identified from surface ship data. In conjuction with the acquisition of Sea Beam, Jason, and DSL split-beam side-scan imagery, three DSV Turtle dives were undertaken to provide the crucial ground truth for the interpretations made using the surface ship data. The first dive, on 27 Nov 1989, was for reconnaissance, to provide preliminary ideas regarding the character of the seafloor and the nature of the terrain; bottom samples and photography gave us the first real view of the seafloor geology. The second dive, on 29 Nov1989, was planned to cross a major fault interpreted from the Sea Beam contours and, if possible, collect samples of fault rocks on a small ledge near the middle of the steep escarpment; this dive was an unqualified success on both accounts, thereby allowing us to prove our hypothesis about the fault location. The final dive, on 1 Dec 1989, was planned to traverse the shallow region of the detailed Jason and side-scan sonar survey and to provide ground truth, including rock samples, of the seafloor geology.

ARRANGEMENT OF TURTLE EQUIPMENT





Universal Transverse Mercator Projection * Scale = 1:15000 USNS Laney Chouest/SeaBeam



FORTYMILE BANK DIVE TRACKS